Urban Parameterizations for Mesoscale Meteorological Models

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Objectives: The transport and dispersion of chem-bio agents within cities is strongly impacted by building obstacles. Computational fluid dynamics (CFD) models are being improved as part of the DOE CBNP M&P program in order to explicitly simulate the flow fields around groups of buildings. Even with the world's fastest computers, however, the spatial domains of the CFD models are limited to regions on the order of kilometers. Transport of chem-bio agents over larger distances must be handled by mesoscale atmospheric codes. These mesoscale atmospheric codes, however, cannot "see" the buildings explicitly because the spatial resolution, or grid size, of the models is on the order of kilometers. Buildings and urban landuse significantly impact the micro- and mesoscale flow fields, altering the wind, temperature, turbulence, and radiation budget fields (e.g., Bornstein, 1987; Hosker, 1984). For chem-bio releases within cities that will travel within the urban canopy, accounting for the urban influence on the meteorological fields is essential for accurately quantifying the transport and dispersion of the chem-bio clouds. Since mesoscale numerical models do not have the spatial resolution to directly simulate the fluid dynamics and thermodynamics in and around urban structures, urban canopy parameterizations are needed to approximate the drag, heating, radiation attenuation and enhanced turbulent kinetic energy (tke) produced by the sub-grid scale urban elements.

Recent Progress: We have developed relatively straightforward urban canopy parameterizations based on modification of Yamada's (1982) forest canopy parameterizations (Brown and Williams, 1998). These parameterizations add drag to the momentum equations, mechanical turbulence production to the turbulent kinetic energy and turbulent length scale equations, anthropogenic and roof heat to the temperature equation, attenuation and trapping due to buildings to the short and longwave radiation equations, and urban landuse properties to the surface energy budget equation. Figure 1 illustrates the impact of the urban canopy parameterizations on the mesoscale meteorological

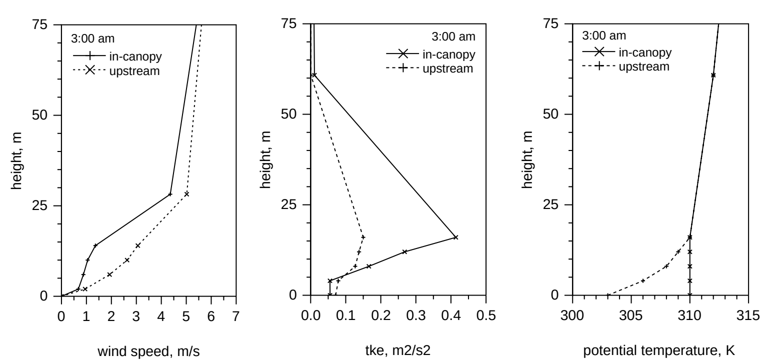

Figure 1. These plots show the influence of the urban canopy parameterizations on the meteorological fields. Model-computed vertical profiles of wind speed, tke, and potential temperature at non-urban (upstream) and urban (in-canopy) sites. Canopy height = 22 m.

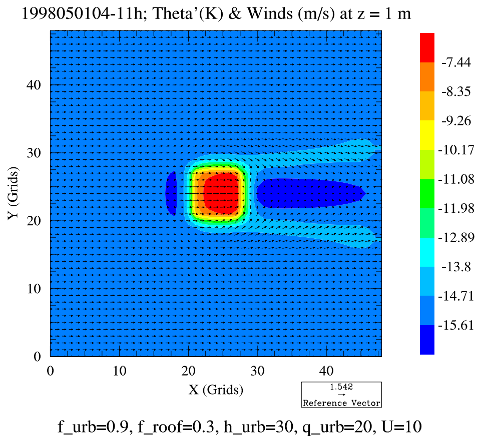

Figure 2. Urban heat island produced at night by the COAMPS code using the urban canopy parameterizations. Shown is the horizontal cross section of the potential temperature deviation from the initial state. f_{urb} is the urban fraction, f_{roof} the roof fraction, h_{urb} the canopy height, U the initial wind speed and q_{urb} the anthropogenic heating term.

variables. In a real-world application, the urban canopy parameterizations were found to significantly alter the mean and turbulent flow fields in the El Paso/Ciudad Juarez region (Brown and Williams, 1997). Comparison with field data is currently ongoing.

Leach and Chin (1999) have recently incorporated these urban canopy parameterizations into the COAMPS mesoscale meteorological code, the prognostic atmospheric code scheduled to be integrated into the CB-ARAC emergency response atmospheric dispersion modeling system. Results indicate that this urban canopy parameterization is able to simulate the night-time urban heat island phenomenon (see Figure 2) and the day-time urban cooling in the condition with weak anthropogenic heat as detected in many field studies (e.g., Oke, 1982; Bornstein, 1987). However, the timing of urban cooling / heating transition near the sunrise is insensitive to the input parameters, such as urban and roof fractions, and thereby the maximum urban heating effect remains nearly unchanged for various specified urban canopy conditions under the given anthropogenic heating. Our preliminary results show that this drawback is attributed to the assumption of zero heat capacity of the roof in the urban canopy parameterization.

Future Progress. Research work needs to be performed in three overlapping areas: model physics improvement, urban database generation, and model/parameterization validation. Model physics improvement includes possible modifications to the assumptions and equations making up the current urban canopy parameterizations. The urban database generation involves careful review of geographical databases and past laboratory and field experiments, as well as performing new experiments. The urban datasets are needed for developing improved model physics, for specifying parameters in the urban canopy parameterizations, and for validating the canopy parameterizations. Model and canopy parameterization validation includes testing the individual components of the urban canopy algorithms, quantifying parameter uncertainties and model sensitivities, and comparing field data to atmospheric mesoscale model results using the urban canopy parameterizations. Our approach here is to keep a healthy balance between keeping the parameterizations as simple as possible and adequately describing the urban canopy phenomena. We need to be careful not to add too much detail into the parameterizations, as this means more input data is required at higher fidelity and this data currently is just not available. LANL and LLNL scientists will continue to work closely together on urban canopy parameterization development, validation, and application.

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